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C-5 LAUNCH FACILITIES

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Introduction

Launch facilities and ground support equipment are a function of the planned use and deployment of the vehicles to be launched. With the President's stated national objective of landing man on the moon and returning him safely to earth within this decade, it becomes imperative to develop launch vehicles and facilities capable of achieving this goal.

It is readily apparent that the weight difference between the one-ton Mercury spacecraft and the approximately 45-ton Apollo for moon flights necessitates a launch vehicle with considerably increased thrust to attain orbital and escape velocities. Proportionately, the launch facilities require the capability of handling the larger space vehicles.

C-5 Launch Vehicles

The C-5 space vehicle which will be used to launch the spacecraft for man's lunar landing develops twenty times as much thrust in its first stage alone as do the Atlas vehicles used to launch the Mercury spacecraft. The C-5 has been selected as the launch vehicle to launch a three-man space crew into lunar orbit, land two of

Slide 1 them on the moon and return all three safely to earth. Figure 1 shows some of the significant characteristics of the C-5. The first stage, the S-IC, is 138 feet long and has a total thrust of 7.5 million pounds at sea level. The second stage, the S-II, is approximately 82 feet long, and will produce one million pounds of thrust when operating in space. Both the S-IC and S-II are 396 inches in diameter.

The third stage, the S-IVB, is 59 feet long, 260 inches in diameter, and will produce a thrust of 200,000 pounds when operating in space.

The C-5 launch vehicle, with the Apollo on top, is 360 feet tall. Fully fueled, it weighs over 3,000 tons. It has the capability to place 120 tons in low earth orbit, and 45 tons into escape for lunar missions.

Launch Complex 34

Slide 2 Conventional launch complexes, as demonstrated by Launch Complex 34, which is used to launch Saturn C-1, is an enlarged, extrapolated application of the basic launch complex developed for research and development work. Some of its disadvantages include large capital investments, low launch rates, repetitive checkout operations, necessary remating of the vehicle to ground equipment, and close proximity of the launch control center to the launch pad.

The initial cost of Complex 34 was very close to 45 million dollars. The major costs involved are represented in the launch service structure, the blockhouse, the launch pad, the propellants systems, and associated underground test rooms.

The primary disadvantage of this complex and its major elements is the very low rate of utilization. To launch the Saturn C-1 requires approximately two months on the pad to perform the assembly and checkout and one month after launch to rehabilitate the pad launch equipment. This limits the launch site utilization to four vehicles a year, a very low rate for an investment of this magnitude.

As is apparent, to design and build the Complex 34 service structure itself was an engineering challenge of the first order. The height required to straddle the

Saturn vehicle and perform assembly and the various service functions, the mobility required to park it at a safe distance before launch, and the rigidity required to withstand hurricane winds of 125 knots, all combine to make this single element one of the most costly features of the complex. These factors indicate that future rockets, when designed to a scale two to three times that of the Saturn C-1, would require a service structure which would pose tremendous cost and engineering problems.

The blockhouse, or launch control center, is the major control and coordinating point of the vehicle and the active ground support equipment in the final stages of launch. The present launch control center evolved from the bunker type, where launch operations were conducted for relatively simple rocket configurations. As the rockets grew in size there was a corresponding growth in the number of controls, measurements, and checkout lines. This, in turn, required additional personnel near the launch pad, resulting in a massive reinforced concrete shelter for the protection of personnel and equipment. An additional reason for locating the launch control center near the vehicle was the need to limit cable lengths because of the analog techniques used between the vehicle and the control center for all measurements, controls, and stimuli. The analog signals, by their inherent characteristics are limited in the distance they can be accurately transmitted because of voltage drops and interference induced by other electromagnetic currents.

The launch pad and the launcher pedestal were also developed from previous design configurations to accommodate the Saturn C-1. Rooms are provided below the pad for ground support equipment, checkout terminal panels, instrumentation panels, generators, gas distribution lines, and cables run from the control center to the vehicle. The Complex is not adaptable, as changes in vehicle design would require major modifications to facilities and equipment. These changes would require many months during which the total launch site would be inactive for launch operations.

The assembly operation has followed established methods for checking out vehicle stages prior to assembly. After shipping the stages from the point of manufacture, it has proven advantageous for reliability reasons, to again test the various components and systems mostly in a horizontal position, to verify that no damage occurred in transit, and to verify calibration curves for the onboard measurements. After the stages are checked out in the assembly building, transported to the pad, erected, and the total vehicle assembled they are connected to the launch control center panels for a final series of checkouts to verify that the launch complex around support equipment is in proper working order.

The functions of the assembly building have also been carried into the larger space vehicle operations. The major disadvantage to this procedure is the time consuming repetition of all these tests after the vehicle has been assembled on the launch pad.

A reasonably probable schedule of future launch frequencies with a minimum of 24 vehicles per year would require approximately 6 of the Saturn C-1 type complexes. Also, for each launch site, a complete launch crew composed of rare experience and skills would be required to launch each vehicle.

A consideration that must be planned for is that of salvo launch operations, wherein several of these large vehicles could be launched within short periods of time to meet space rendezvous requirements.

The possibility of a vehicle misfiring during launch must also be considered. Under the conventional concept, the space vehicle must be rechecked and remain on the pad for the next available launch window. This, in turn, would cause sequential delays in missions shceduled to follow from the same pad.

Explosive and Acoustic Level

Consideration must be given to the possibility of an explosion if one of the large rockets, with its total fuel capacity, should explode during launch, either by a stray voltage ignition of the solid rockets onboard, rupture of a fuel tank, or a failure of the propulsion system shortly after liftoff which would cause the vehicle to fall back on the pad.

Analysis of these explosive equivalencies indicates that each pound of fuel onboard the vehicle could result in an explosive force up to 25 percent of that obtained from a pound of TNT. This explosive force, computed for the one million pounds of fuel onboard a C-1, could equal the force of 250,000 pounds of TNT. The C-5 will have six million pounds of fuel, with the explosive equivalency of 1.5 million pounds of TNT. Serious consideration must be given to protecting the vehicles on adjacent pads. The separation distances between pads must provide protection from the over-pressure from an explosion, should it occur. The over-pressure of 0.4 pounds per square inch has been designated as the pad-separation distance criterion.

Another consideration is the sound pressure level developed from the engines during launch. The sound pressure level has been measured from our Saturn C-1 launches to date. By extrapolating these measurements, safety distances required to keep the noise level sufficiently low for surrounding cities, facilities, and personnel have also been calculated. This map shows the distances required for protection from both explosive

Slide 3 forces and sound pressure. This is the existing Cape Canaveral area and Complex 34 is located here. Also shown is the land adjacent to Cape Canaveral which was purchased for C-5 and Nova complexes. The new NASA area totals approximately 87,000 acres, with over 30 miles of coast line.

Launch Complex 39

The overall concept of the new launch facilities required for C-5 indicates the approach planned to eliminate some of the disadvantages of previous launch complexes.

Slide 4 The most apparent difference is the mobility of the launcher-umbilical tower and the launch vehicle. The basic concept is to erect the entire space vehicle in a sheltered environment and check it together with all umbilical connections made to the ground support equipment so that tests remain valid. The space vehicle is then transported to the launch pad without separating the essential checked-out connections from the ground support equipment; leaving it on the minimum launch pad for the shortest possible time before launch.

The mobile concept for the launch complex requires an installation which covers many thousands of acres. The vertical assembly and checkout building is located approximately three miles from the pads and thus outside the explosive blast radius, even if the vehicle should turn backward and have to be destroyed. The pads are separated from each other by a distance of 8,730 feet, and each pad has a noise-level buffer zone extending to 19,000 feet.

Vertical Assembly Building

The most imposing construction of this immense complex is the vertical assembly building. It is planned to construct the building in segments to meet the initial launch schedule and at the same time keep pace with the increase in firing density. The building will be constructed to perform assembly, checkout, and launch control operations. The same panels and ground equipment which will be used to checkout the vehicles will also be used to control the launch. The capability of performing

Slide 5 these varied operations eliminates the necessity for locating a separate and reinforced launch control center or the heavy assembly and service sturcture near the pad.

Slide 6 The Vertical Assemb ly Building design is relatively simple despite its versatility and dimensions; 524 feet high, 513 feet deep and 674 feet long. The height was established to handle the tallest configuration of the assembled C-5, using a crane hook height of 455 feet. The building's distance and location from the launch pads was determined by impact probability studies; thus construction criteria are controlled by conventional parameters, including hurricane protection. In addition, it can be a closed structure, thus permitting a continuous schedule of work in controlled environment.

The multiple-bay feature of the assembly building will make it possible to schedule a rapid sequence of launches, as will be required for refueling, rendezvous, or "in-orbit assembly" missions. Assembly operations can also be staggered to provide a steady and predetermined launch rate. The bays of the assembly building are also sufficiently adaptable to permit handling the C-5, the C-1B, or other vehicle configurations not yet developed.

The multiple bays also permit more flexibility in the application of technical talent. If an assembly or checkout technician is required to work on another vehicle he can be on the scene in a few minutes and he can also be scheduled to move from vehicle to vehicle, performing his specialized skills in accordance with the launch schedule. This in turn increases the technician's specialized skill, since he can be occupied for longer periods of time in his particular field. This contrasts with the time previously spent in traveling from one complex to another complex several miles away.

Automatic Checkout

Fully automated checkout techniques are prerequisite to the mobile concept. Launch vehicle, spacecraft and all ground support equipment must be developed accordingly.

Slide 7 This depicts the major control elements for the testing and launching of the C-5.

1. The launch vehicle is mounted on the launcher with its umbilical connected to the vehicle. Its computer complex is located in the base of the launcher as an integral system. This complex in itself is completely capable of verifying and checking the complete vehicle system. However, for reasons of personnel safety, it is not possible to man this particular facility during launch operations.

2. A similar installation is located in the launch control center some distance from the pad. A coaxial cable data link is used to connect the computer complex of the launch control center with the computer complex of the launcher. When operational control of the system is transferred to the launch control center, the computer complex at the launch pad becomes a slave to the master computer complex in the launch control center.

3. Information generated in analog form at the pad during prelaunch checkout and countdown is converted to digital form for transmission to the launch control center. Here it is reconverted to analog form for display. This process avoids those disadvantages mentioned earlier concerning the transmission of analog signals over long distances. Final verification of the entire vehicle and launch complex system will be performed from the launch control center as would the actual launch.

4. The present technique of preparing a space vehicle for launch is for systems engineers to test and calibrate the components, subsystems and systems separately, disconnecting and isolating these as much as possible from all other systems. Then, a process of gradual integration is followed until the total configuration is ready for launch. Every time a major component is replaced, or a vital connection is broken, time consuming but necessary revalidating processes are repeated.

5. Using an automatic checkout/computer concept, the components and systems will be provided with the capability of continuous checkout; but instead of technicians breaking into the systems, access to all important functions and data measuring will be provided by design in the vehicle. The checks will be performed by computers in which the tests are programmed; thus manual operations can be reduced by several orders of magnitude.

6. To gain access to all the various points of interest, and derive valid data, subsystems and components must be isolated, not by manual separation, but by suitable separation devices that will later "fly along", yet be subject to manipulation during checkout. In other words, each system or component to be checked, must be separated or isolated, stimuli addressed to it, and the response measured and compared with a set of standards or tolerances. If the measured response is outside of tolerances prescribed for the component, then the checkout is automatically stopped, and an indication given as to the problem area. This will require some more valves, relays, pressure taps, wiring systems, and high or low pressure piping systems, to name only a few of the additionally required components. All of these must be considered in the overall vehicle design, but they will reduce the human error in checkout

as well as reducing the actual checkout time, and will extend lifetime of components.

Launcher-Umbilical Tower

A major element of the mobile concept is the launcher-umbilical tower (LUT).

Slide 8

It is primarily a transportable launcher which carries the connected umbilical tower and the vertically assembled C-5. Its function is to allow the vehicle to be assembled and mated to the umbilical connections and then checked out in the vertical assembly building. Each bay of the building will accommodate one LUT upon which a space vehicle will be erected. After vehicle assembly and preparation in the VAB, the launcher-umbilical tower and the connected vehicle will be transported to the launch site and the LUT will then serve as the launch platform.

The nominal size of the launch platform will be 137 feet wide by 170 feet long by 25 feet high. The 380 foot high umbilical tower will be mounted at one end of the LUT. The estimated weight of the launcher-umbilical tower is 10,500,000 pounds. The tower contains elevators, cables for instrumentation, lights and communications, a pneumatic distribution system, umbilical swing arms, and cryogenic fill and vent piping.

At the launch pad, the LUT will be mated to the launch facility and the data link cabling. Service and communication lines between the LUT and the facility will be connected to form an integrated launch system.

Transporter

Several methods of transporting the launcher-umbilical tower were considered; including barge, rail, and crawler transporters. Comparison of these modes indicated the crawler-transporter to be the best method, with the transporter separated from the launcher-umbilical tower so that it can be used independently. It can also be used

Slide 9 to move other heavy loads such as the arming tower.

The nominal weight to be lifted by the transporter will be approximately 11.5 million pounds. It is a self-propelled prime mover 131 feet long, 114 wide, and with lifting and leveling cylinders located on a 90-foot square.

Aboard the transporter will be self-contained hydraulic leveling and steering systems and a power plant capable of generating up to 4,000 horsepower. The steering is designed to negotiate a mean turning radius of 500 feet and the supporting cylinders will maintain level with $\pm$ ten minutes.

The transporter will be designed for a normal speed of approximately one mile per hour. The platform will remain within $\pm$ ten minutes of horizontal at all times, even while negotiating a five percent grade with a 300-foot long vertical transition curve at either end. Acceleration and deceleration during movement, or due to stop and start, will not exceed 0.08 g or 2.58 feet/sec^2.

The crawler transporters of the size required have been, and are, in use for industrial purposes, thus no expensive research and development program will be required. By using designs proven by industrial use, operational and maintenance problems should also be minimized.

The transporter will travel on crawler-ways consisting of crushed stone surface, soil cement base, and stabilized sub-base. The roadways will be elevated approximately eight feet above sea level and the approach to the pad will be graded to a five percent slope to allow the LUT graded access to the elevated launch pad. The crawler ways are designed to support 17 million pounds. With the planned loading of the track area now under design, specific pressure will be 9,000 pounds per square foot.

Arming Tower

Slide 10 The arming tower is another basic element of the mobile concept. It is not the conventional assembly and service tower but has the function to provide access required for the installation of major ordnance and equipment on the assembled launch vehicle which may be too dangerous to accomplish in the VAB. It will also provide access to the assembled vehicle on the pad from the outside as may become necessary. The tower will be a rigid-frame steel structure approximately 415 feet high, 150 by 125 feet at the base, and 80 feet square at the top. It will weigh approximately 7,000,000 pounds. The tower will be equipped with a stiff-leg derrick, capable of lifting approximately 40 tons, and elevator system, enclosed work platforms, and other equipment necessary to perform its functions. It is planned that the tower will be parked near the crawler-way and that the vehicle will be mated to the tower for ordnance installation while enroute to the pad. However, the tower has been designed to be mobile to permit servicing of the vehicle while on the pad, if necessary. One tower is planned to serve on <u>all</u> pads that may require its functions. It is expected

Slide 11 that the Apollo spacecraft may require this service.

Launch Pads

Each of the launch positions will consist essentially of a concrete foundation

Slide 12 housing a flame deflector, plus associated fuel, gas, and electrical lines and connections. Complex 39 will have up to four such positions, with proper separation to accommodate salvo launches, should they be required.

Because the launch position is a relatively simple installation and is not equipped with complicated and costly facilities, little damage from exhaust flames is expected and consequently, a minimum investment in cost or time of rehabilitiation should result.

Summary of Advantages

One of the most rewarding aspects of the mobile concept is the short stay time at the launch site and resulting high pad utilization. Instead of tying up an entire launch complex for the pre-launch preparations, the vehicle will be prepared in the VAB and remain at the launch site only for about a week. This permits frequent use of the launch pads for launch operations while the specialized job of stage and vehicle preparation is performed in the protected environment of the VAB.

Because of mobility and the relatively short time at the launch site, vehicles will be scheduled with more flexibility than is now possible. At the present time a vehicle and its launch pad are inexorably committed to each other until the vehicle is launched. On the new complex a vehicle may be moved back to the assembly building any time prior to liftoff; or if it remains at the launch position until liftoff, it will occupy the site for about a week. This factor, plus the multiple bays and launch positions, will make it possible to pinpoint launch dates more accurately, prepare launch schedules further into the future, or change mission priorities.

This new concept is based on a high launch rate and takes into consideration the complexity of future space vehicle configurations. It will cost less money, operate more efficiently and be capable of launching vehicles at a more rapid rate than is now possible. Up to 75 vehicles per year could be launched from four launch possitions, but a support capability for this number of launches is not currently planned.

Centralization of launch pads, and the ability to perform checkout operations in the assembly building permits a definite manpower saving realized primarily at specialist and supervisory levels. Comparison with operational fixed complexes indicates that expansion can be accomplished with a minimum increase in personnel. Ability to work in the same area, reduced transfer time between bays as opposed to between complexes, and reduced direct and indirect labor costs are additional benefits of the mobile concept. A new launch vehicle configuration does not require "down time" of the facility for adaptive changes, but only a different LUT.

In addition, the adaptibility of the mobile concept enhances its overall value. Separate assembly buildings for liquid and solid propelled vehicles can be located on the same complex. By modifying the launchers and their umbilical towers to fit individual configurations, the assembly buildings become adaptable to a variety of manned space vehicles. Versatility can also be demonstrated by the capability of moving vehicles to the pad or back into the assembly building in a few hours, at the same time maintaining their flight readiness, even under hurricane conditions.

Conclusion

We have analyzed our existing launch facilities, noted their shortcomings, and the need for a newer concept. We have studied the concept derived, from all considerations, and believe that it is the most feasible approach to the overall launch facilities problem.

Admittedly, we face great challenges of engineering design and construction, however, architectural and engineering design criteria for the new launch area and its facilities have already been established, contracts have been awarded, and construction is currently underway on some of these facilities.